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Great Lakes Update

Great Lakes Storms

Throughout the year weather systems drift across the Great Lakes, producing clouds, rain and snow, and summertime thunderstorms. Most of these atmospheric systems are nothing more than an annoyance for the residents in the region, including shoreline property owners (riparians), and those who make their living plying the Great Lakes. However, during the current high water levels, each approaching storm is scrutinized for strength and movement to assess whether storm waves will be of the size and out of a given direction to cause serious threats to coastal property and safe navigation.

During the spring and fall, storm systems tend to be stronger due to contrasts in air masses crossing the Great Lakes region. In turn, waves on the lakes increase in height and become more powerful.

During the fall, in particular, the jet stream that separates the cold Canadian air to the north and warm Gulf air to the south migrates southward across the Great Lakes and can cause significant storms.

When water remains still, it may not pose a significant threat, even under the current high water level period. However, when the water is set in motion by driving storm winds, the resulting wave energy is expended higher on the shoreline profile, causing an increase in beach erosion and bluff recession. Also, lowland flooding under these conditions is more chronic, especially in areas where the shoreline is poorly protected or sea walls are easily overtopped by breaking waves.

Strong winds blowing parallel to the axis of a lake (such as a southwest wind on Lake Erie) or across ample distance of a lake surface (‘fetch’) can result in a phenomenon known as *wind setup*, where the lake water is ‘pushed’ by the wind and piled up on the leeward shore. The difference between the average still water level and average storm water levels is termed *storm rise*. Conversely, water levels may drop as much as three or four feet on the windward side of the lake. Because the Great Lakes are at the latitude of predominantly westerly winds, the eastern shores of the lakes tend to endure the greatest storm rises and strongest wave energy. Each lake’s size, shape, depth, shoreline composition and orientation to storm winds play key roles in the extent of impact of major storms.

The term “storm rise”, however, does not include any additional inundation that can be caused by "wave runup." Wave runup is the term for the propagation of waves onshore and the height which they may reach. Because much of the Great Lakes region is composed of either ancient lake bottom sand and silt, or glacial deposits of sand, clay and gravel, much of the natural Great Lakes shoreline is susceptible to rapid erosion.

On Lake Superior (which is somewhat triangular), strong storm winds generally will result in storm rises of .5 to 1 foot at most shoreline locations. However, sustained 30 knot winds blowing along the east-west axis of the lake can generate waves with heights of 10 to 15 feet.

Lake Michigan's north-south orientation can lead to the creation of a maximum storm rise of around 3 feet along its southern shore during strong northerly wind events. However, such events tend to be very infrequent since low pressure systems cause counter-clockwise circulation of the air. Because of this circulation pattern, strong winds from the north tend to curve to the eastern shore of the lake. This can subject shoreline communities in southwest lower Michigan to waves that have essentially traversed most of the 300 miles along the lake's axis. Because of the sand/silt composition of the eastern shore of the lake, and other key factors, the shoreline in southwestern Michigan is suffering the most rapid recession/erosion of any shoreline in the Great Lakes during this higher than normal water level period.

On Lake Huron, strong winds from any easterly component can batter the 580 miles of Michigan shoreline. However, the most vulnerable area tends to be Saginaw Bay, where strong northeast winds cross the widest portion of the lake. This condition can occasionally trigger lowland flooding around Bay City and a temporary reversal in the flow of the Saginaw River.

Lake St. Clair's small size, nearly round shape and shallow depth tend to cause a rapid change in water levels in response to changing wind and weather conditions. Lake St. Clair's water circulation patterns are intimately connected to wind speed and direction. The lake can rapidly become very turbid and overtop sea walls ringing the lake. The northwest quadrant and delta region of the lake is very susceptible to lowland flooding during high water level periods as 4-foot or greater waves, generated by southerly winds, can easily sweep over bermed shoreline into backyards and across roads.

The greatest wind setups in the Great Lakes are found on Lake Erie. Because of its east-west orientation, very shallow western end, and 240 mile of fetch distance, atmospheric disruptions can cause significant local changes in water levels. Under a strong northeast wind, the storm rise in the west end of the lake can range from 1- to 2.5-feet. During the current high water level period, the western end is very susceptible to storm rises and the power of wind-driven waves. Since this area has a very gentle slope, typified by its historic marshland characteristics, a 1-foot rise in water levels can translate into a several hundred foot encroachment of water inland. With its long shape, Lake Erie offshore waves have been up to 10- to 15-feet high, and have caused severe erosional problems when they come inshore, especially east of Cleveland, Ohio.

The degree of influence of storms over Lake Erie's water level is best described through the following example (which is a recurring phenomena). During the early morning hours of February 16, 1967, a southwest wind recorded at 52 mph (at Buffalo, New York) helped create an almost 15-foot difference in the water surface elevation between Toledo, Ohio and Buffalo, New York!

Lake Ontario is similar in size and shape to Lake Erie. However, Lake Ontario has a greater average depth which dampens storm rises somewhat , but they do reach 1- to 2-feet, particularly along the eastern shorelines which also endure greater wave runup forces.

Of major concern to commercial shipping interests across the Great Lakes is the abrupt change in water depth during storms. Between spring and fall storm seasons, wave heights can typically range from five to greater than twenty feet in height on the open waters, and dissipate somewhat as they break in shallower nearshore waters. Because of their modest depths, Saginaw Bay, the south end of Lake Huron, and Lakes Erie and St. Clair can become very violent in a short period of time.

Ship captains carrying more cargo during the current high water level period have to be very cognizant of their vessel's draft in respect to where they navigate in storm conditions. Though we have all experienced some nasty storms in this part of the country, three are referred to most often by mariners.

The most familiar story is that of the *Edmund Fitzgerald,* one of the largest freighters on the lakes during her time. Fierce waves on Lake Superior, reported to be 20- to 25-feet high, felled the mighty ship on November 10, 1975, with all 29 crew members being lost. The second major event was a storm that occurred on November 11-13, 1940 called the Armistice Day Storm. This storm claimed two ships and 100 men on Lake Michigan near Pentwater, Michigan. However, few will ever compare to the great storm of November 7-11, 1913.

On Friday, November 7, 1913, a unique weather pattern was shaping up that would pit bitter arctic air from the north polar regions against warm, moist tropical breezes. The branches of the strong arctic and subtropical jet streams would steer two very different storms on a collision course, resulting in the formation of one cataclysmic storm right over the Great Lakes.

A normal-strength low pressure system over Minnesota, dragging cold air behind it across the Canadian plains of Manitoba, was on a course for Marquette, Michigan. The U.S. Weather Bureau issued standard storm warnings for the entire Great Lakes, based on the observed moderate strength of the storm and the general increase in intensity that occurs in storms crossing the lakes. Meanwhile, the subtropical jet was steering its own low pressure system (of which the Bureau was unaware) northward through the southeast U.S.

The Great Lakes were teeming with activity, as the shipping season was set to close by Thanksgiving. Freighter captains, ignoring the issued warnings, chose to take their chances on the lakes with one more trip before season's end.

On Saturday, November 8th, the northern storm system moving east toward Sault Ste. Marie, Michigan, suddenly curved toward Alpena, Michigan and stalled. The southern system began to drift northward up the east coast of the U.S. By Sunday morning, November 9th, both storms were combining energies, as frigid arctic air clashed with warm tropical air. As a result, rapid intensification occurred as the two storm centers merged over western Pennsylvania. At Cleveland, Ohio winds were howling off Lake Erie at 60 mph with blinding snow. The city would be paralyzed under nearly 18" of snow in a 24-hour period. By that evening, the storm had reached hurricane strength (74 mph wind) over eastern Lake Erie.

On the open waters, sailors and ships fought for their lives. Mountainous swells of 30- to 40-feet were estimated by experienced crew members. A ship off Harbor Beach, Michigan, on Lake Huron reported 90 mph winds with 30-foot waves, and 75-80 mph winds were logged at Port Sanilac, Michigan, also on Lake Huron. The entire country east of Chicago, Illinois, battled this immense storm for over 40 hours from early Sunday through late Monday. Ships dropped anchor in vain as the wind and waves blew their vessels onto beaches and rocks; navigational aids failed and blinding snow limited visibility to a few feet. Eleven ships completely disappeared from the surface of the Great Lakes and the steamer *Charles S. Price* was found floating upside down on Lake Huron.

All told, over 250 lives were lost, most in the southern horseshoe of Lake Huron. Ships disappeared without a trace, and no one to this day knows exactly where each went down. For those who experienced it, the storm really was a nightmare come true.

For further information on the 1913 storm, see Freshwater Fury by Frank Barcus, 1986, Wayne State University Press. Special thanks for their kind help goes to meteorologist (ret.) Mal Sillars, WDIV-TV meteorologist Paul Gross, and the gentlemen at the J.W. Westcott Co.

Frequently Asked Questions - Updated

How are Great Lakes water levels controlled?

Whenever Great Lakes water levels are being discussed, the control of Lakes Superior and Ontario outflows arises. Lake levels and outflows from all of the Great Lakes are subject to natural climatic, hydrologic and hydraulic factors. However, outflows from Lakes Superior and Ontario can be directly controlled by artificial means. The outflows from Lakes Michigan-Huron, hydraulically connected through the wide and deep Straits of Mackinac, Lake St. Clair, and Lake Erie are controlled by nature.

Regulation of Lakes Superior and Ontario has provided controls for the outflows of these two lakes since 1921 and 1958, respectively. The goal of the regulation plans for these lakes is to keep their levels within a specified range, near their long-term averages. The outflow controls are provided by a series of hydropower facilities, navigation locks, and gated control dams. The control of the outflows of these lakes allows the levels to be maintained within a smaller range than is possible without regulation. Lake Superior outflows are currently regulated using Plan 1977-A, while those of Lake Ontario are regulated using Plan 1958-D.

What is Plan 1977-A and how is it implemented?

In October 1979, Plan 1977 was activated, incorporating a philosophy of systemic regulation. Plan 1977 was revised in 1990 to bring the regulation plan up- to-date and improve operational efficiency. The revised plan known as Plan 1977-A is the current operating plan. Use of Plan 1977-A was approved in 1990 by the International Joint Commission (IJC) and is implemented by the IJC's International Lake Superior Board of Control. It is the latest in a series of regulation plans which incorporate a balancing technique between the levels of Lakes Superior and Michigan-Huron. Plan 1977-A complies with the regulation objectives and criteria contained in the IJC's Orders of Approval dated May 26-27, 1914 as well as subsequent 1978 and 1979 Supplementary Orders of Approval. Generally, Lake Superior outflows are determined at the beginning of each month. The releases, once they are determined by the regulation plan, are made through the various structures on the St. Marys River.

What are the objectives of Plan 1977-A?

Central to Plan 1977-A is a relationship which determines the monthly Lake Superior outflow necessary to balance water levels of Lake Superior and Lakes Michigan-Huron. This balancing relationship takes into consideration their historic range of fluctuation and the differing sizes of the lakes and their drainage basins. The fundamental goal of the balancing relationship is to make the water stored in the two lakes (represented by the water levels) proportionally the same. If the level of Lake Superior at the beginning of the month is proportionally greater than that of Lakes Michigan-Huron, the relationship will call for a Lake Superior outflow greater than average. Conversely, if the beginning of month level of Lakes Michigan-Huron is relatively higher than that of Lake Superior, the resulting outflow will be lower than average.

What limits are built into Plan 1977-A?

Plan 1977-A incorporates level and flow criteria with the objective of meeting IJC requirements as well as working to satisfy the realities of the physical limitations of the system and the local interests on the St. Marys River. The objectives include maintaining Lake Superior levels within a range of 603.2 and 599.6 feet (IGLD, 1985) based on water supplies of the past (1900 - 1976). Generally, Plan 1977-A works very well in meeting its balancing objectives. During periods of higher than normal (or lower than normal) lake levels, both on Lake Superior and in the lower lakes, local interests around the lakes have desired preemptive actions. Such actions, however, are restricted by the Orders of Approval. The Orders of Approval do not grant the International Lake Superior Board of Control discretionary authority to affect "hands-on" deviation from Plan 1977-A.

Additional details and information is available in the *Great Lakes Levels, Update Letter No. 101, "The Regulation of the Outflow from Lake Superior*." Copies are available from the U.S. Army Corps of Engineers, Detroit District office on request.

How are Lake Ontario outflows regulated?

Three plans have been used to regulate the outflows of Lake Ontario. All of these plans were designed to meet the objectives specified in the 1952 Orders of Approval and the 1956 Supplementary Orders of Approval. Plan 1958-D, the present regulation plan, consists of a supply indicator, two basic level-outflow relationships, seasonal adjustments, and a number of maximum and minimum outflow limits. The basic regulated outflow is derived from relationships, the "basic rule curves", which give outflow as a function of lake level and the adjusted supply indicator. The basic regulated outflow is modified by applying seasonal adjustments which function to store water in the winter, spring and early summer months. The seasonal adjusted outflow is then compared to several maximum and minimum outflow limits which vary through the year. If the seasonal adjusted outflow is between the minimum and maximum limits applicable to the period, it is adopted as a plan flow. Otherwise the applicable outflow limit becomes the plan flow. Lake Ontario's outflow is adjusted weekly by the IJC's International St. Lawrence River Board of Control, according to Plan 1958-D.

What is the goal of Plan 1958-D?

The goal is to maintain the levels on Lake Ontario within a target range of 243.3 to 247.3 feet (IGLD, 1985).

How does Plan 1958-D work in the winter?

During winter operations, ice becomes an important factor. For a short period at the beginning of the winter, outflows from Lake Ontario are often temporarily reduced to assist in the formation of a stable ice cover at the outlet of Lake St. Francis and in the international rapids section of the St. Lawrence River upstream of Cornwall, Ontario, and Massena, New York. Ice booms are also located at several sites in the river to help this process. A breakup of the ice cover can cause an ice jam and result in severe difficulties in flow regulation and hydropower production. After a stable ice cover is formed, flows in the river are gradually increased to offset any temporary flow reductions.

What deviations can be made to Plan 1958-D outflows?

Plan 1958-D was designed to satisfy the criteria for the regulation of Lake Ontario specified by the IJC for the water supplies experienced from 1860 to 1954. It was recognized at the inception of Plan 1958-D that with supplies outside the range of those of 1860-1954, the outflow limits incorporated within the Plan would result in violations of the IJC criteria. Therefore, deviations from the Plan would be necessary in such extreme supply situations. This led to the inclusion of criterion "k" in the IJC Orders of Approval for the regulation of Lake Ontario.

Criterion "k" states that if supplies are greater than in the past (i.e. pre-project) all possible relief is to be provided to the riparian owners upstream and downstream. If supplies are lower than those of the past, all possible relief is to be provided to navigation and power interests. In addition, the IJC has given the International St. Lawrence River Board of Control the authority to make discretionary outflow deviations from the outflow specified by Plan 1985-D if the deviation is to benefit one or more interests without any adverse impacts to any other interest.

Additional details and information is available in the *Great Lakes Levels, Update Letters No. 75 and 77, "Lake Ontario Regulation"*, and *"Lake Ontario Regulation Plan Improvements"*, respectively. Copies are available on request from the Detroit office of the

Corps.

Lake Michigan Potential Damage Study

The Detroit District of the U.S. Army Corps of Engineers has initiated an extensive and long-term assessment of potential shoreline damages over the next 50 years due to fluctuating lake levels along the Lake Michigan shoreline. The study, started in October 1996, is expected to last up to 3 years, and is dedicated to meeting several of the recommendations that came out of the 1986-1993 IJC Great Lakes Levels Reference Study.

Specifically, the IJC Reference Study recommended that the economic value of all shoreline interests be objectively assessed in terms of “potential damages”, that being those damages that could occur under differing hydrologic conditions or alternate management approaches to lake level controls. This recommended approach differs from previous “damage surveys” conducted in the 1970's which were limited to actual losses which occurred under a specific extreme lake level condition. The Lake Michigan study is expected to look at potential damages that could occur if the lake levels were higher or lower than what has been recorded over approximately the last 120 years.

The IJC study also had several other recommendations that the Lake Michigan Potential Damage Study is attempting to address. These include initiation of coastal erosion monitoring programs, updating of coastal process research, updating of land use information, and development of effective public information programs.

The planned three-year study of Lake Michigan shorelines is expected to be the first of an approximately 10-year initiative of assessing the potential damages along all of the U.S. Great Lakes shorelines. Lake Michigan was chosen to be the first since it has severe erosion problems and was the highest damaged lake during the previous high water periods in the 1970s and 1980s. Study participants so far include representatives from the U.S. Army Corps of Engineers, other U.S. federal agencies, international and regional entities (IJC and Great Lakes Commission, respectively) state agencies (including Illinois, Indiana, Michigan and Wisconsin), and academic institutions (Sea Grant Universities, etc.).

Potential damages will be assessed for all affected shoreline interests including residential property, commercial-industrial-institutional facilities, manufacturing and shipping, retail and other commerce, parks and recreational facilities, commercial fishery, and recreational boating and sports fishery. Community-based impacts such as tourism, water supply and wastewater treatment, dredging and channel maintenance, and structural protection are also being factored into these evaluations.

The environmental consequences of extreme lake level fluctuations are also expected to be briefly addressed. These include impacts to fisheries, habitat diversity, endangered and threatened species and archaeological and special natural features.

The first year of the study has been focused on developing the study plan, collecting coastal erosion data and designing computer models for coastal processes and economic assessments. Aerial photography has been collected over large stretches of shoreline for use in updating land use projections into the future. Maps are being compiled into a geographic information system (GIS) to facilitate future analyses and public presentations.